

## RESPONSE OF THE SOLAR FIVE-MINUTE OSCILLATIONS TO A MAJOR FLARE

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**ABSTRACT** — Solar five-minute oscillations of intermediate-degree  $\ell$  were observed both before and after a very strong white-light flare. Intensity images of the full Sun taken on two sides of the Fe I  $\lambda$  5576 spectral line were recorded on film, digitized with 8" spatial resolution, and then converted into Doppler velocities. The data were projected onto both equatorial and polar sectoral modes and Fourier transformed in time. Comparing the resulting power spectra, we find a substantial increase in power in the  $p_5$  ridge of the equatorial modes on the day after the flare; such an increase may be a consequence of the solar flare. When data from all the ridges are considered, there is an average increase in power of only a few percent the day after the flare. This overall increase is probably not significant due to uncertainties from effects of the beating of unresolved modes.

### 1. INTRODUCTION

The manner in which the five-minute oscillations of the Sun are excited and damped is still uncertain. It is likely that these acoustic modes are stochastically driven by the intense turbulence within the convection zone (e.g. Goldreich & Keeley 1977a,b; Goldreich & Kumar, these proceedings). Alternatively, the modes may be self-excited by either a  $\kappa$  or  $\gamma$ -mechanism (e.g. Ando & Osaki 1975). Further, it is possible that a large solar flare may contribute to the excitation of the oscillations (Wolff 1972), for a flare can deposit a substantial amount of energy ( $\sim 10^{32}$  ergs) in a fairly short time (Svestka 1976). Yet the efficiency of the conversion of such energy into acoustic disturbances is uncertain, for it depends significantly upon whether the energy release is confined largely to the atmosphere or also extends into the convection zone.

We were observing solar oscillations with a new setup of the Universal Birefringent Filter (UBF) on the vacuum telescope at NSO/Sacramento Peak when a major white-light flare occurred on 24 April (Day 115) 1984. The flare (of class X13/3B) was one of the largest of this solar cycle. An estimated  $10^{31}$  ergs was seen in continuum radiation (Hiei *et al.* 1986), while the entire flare probably produced  $10^{32}$ - $10^{33}$  ergs. If any flare is going to excite the five-minute modes, this flare should have done it.

We have 10 hours of imaged full-disk Doppler data on Day 115 before the flare started and then 10 hours on the following Day 116. The data have been Fourier transformed in space and time to produce  $m - \nu$  power diagrams, where  $m$  is the azimuthal order of a mode and  $\nu$  is the temporal frequency. The analysis here compares the power in the ridges for the two days, and seeks to assess whether the differences seen before and after the flare are of some significance.

volume may lead to some values being favored over others, but here too the response is likely to be broad. Thus it is presently unclear why the  $p_5$  modes alone appear to show what we deem to be a significant increase in power levels after the flare.

The differences in power for  $p_5$  between positive and negative frequencies after the flare can perhaps be explained. Waves excited by the flare and travelling outward would appear in the observing window at different times due to the placement of the flare near the limb. When observations began on Day 116, those modes travelling prograde would be largely on the other side of the Sun while those moving retrograde would be coming onto the observable side. The waves are of course dispersive and their horizontal propagation speed depends on both  $n$  and  $\ell$ , and thus what happens to wave packets is intricate, especially when considering how they project onto global modes of resonance. Yet we may expect there to be noticeable differences in power levels between retrograde and prograde modes for observations initiated about 12 hours after the flare on Day 116.

The oscillation data considered here were obtained with a preliminary setup of the UBF, and required the use of film as the recording medium. The microdensitometry of such data has been tedious and time consuming, and we therefore have not finished reducing data from a few other days of observations in the same observing run. Such analysis should help place better bounds on the effects of mode beating that can lead to apparent changes in power along a ridge from one day to the next. Nevertheless, we find the substantial increase in power for the  $p_5$  ridge after the flare to be rather enticing. That we were observing on the day of the flare was fortuitous and not easy to repeat. Thus we felt that the data, despite its difficulties, must be scrutinized. Clearly what is needed in the longer term is a data base such as the one to be produced by GONG where one should have a chance to study the effects of at least several flares with continuous coverage.

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